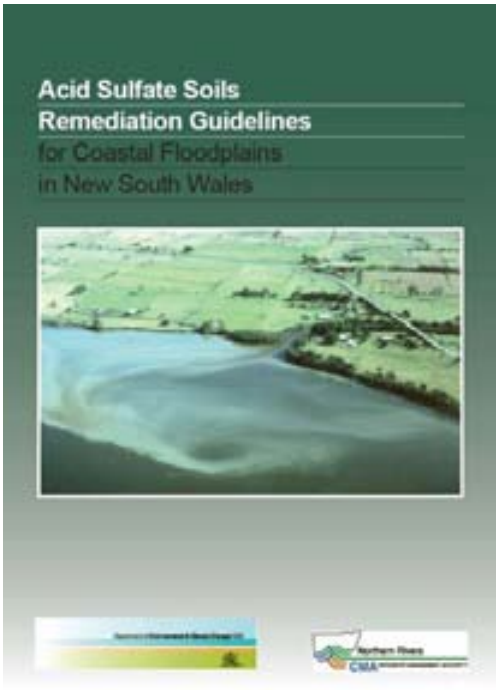
ASSAY

A NEWSLETTER ABOUT ACID SULFATE SOILS

No. 46 August 2008

Losing your boots isn't the only thing you have to worry about when working in the Northern Territory. Jason Hill (NT NREA) took this photo when sampling acid sulfate soils in the Top End. Note the pistol on the hip! Under OH&S it is strongly advised *that a licensed NT Government accredited operator carry a firearm while working in dangerous crocodile habitats…*



Remediation guidelines published (see page 2)

Welcome to edition 46

Thanks to all the ASSAY contributors who got their articles in, with such short notice.

It's a busy time of year and so much is happening in the acid sulfate soil field at the moment. So much so, that some articles needed to be moved to the next edition to prevent the current edition from becoming too long.

For anyone wishing to submit articles for the Sept/Oct edition of ASSAY, the deadline is the 9th September.

Harry

In this edition:

Acid Sulfate Soils Remediation Guidelines for Coastal Floodplains in NSW

The *Acid Sulfate Soils Remediation Guidelines for Coastal Floodplains in New South Wales* have been published. When coastal acid sulfate soil management was first recognised as a major issue some years ago, the most pressing concern was to provide a regulatory basis for the proper assessment and management of new works and development. This was largely achieved with the publication of the NSW Acid Sulfate Soils Manual in 1998. However, limited information was available regarding the best strategies for addressing the existing, often historical, broadacre agricultural problem.

Broadacre ASS remediation strategies have evolved greatly in recent years, largely due to rapid developments in the understanding of scientific and technical issues. At the same time, the objectives of floodplain management have expanded to include a broad range of sometimes competing issues across the floodplain landscape, underlining the need for coordination of floodplain objectives and works across the floodplain landscape. The Guidelines have been prepared in order to meet that need.

The Guidelines focus on those techniques that have proved to be practical and are already in common use:

- neutralisation and dilution by floodgate management/modification
- neutralisation and dilution by restoration of tidal flows to predominantly former estuarine areas
- wet acid containment (ponded pastures), and
- dry acid containment.

The Guidelines examine the science underlying the remediation strategies discussed, and place the requirements of each strategy in the context of the physical limitations of the landscape. It is concluded that containment strategies are likely to be most effective in reducing environmental risk, and further that the opportunities and benefits of ASS remediation are likely to be greatest in the lowest elevation floodplain sites, including the (former) freshwater backswamps and saline wetlands. The Guidelines are intended to be used by those who are involved in ASS remediation, including local council and government agency personnel, consultants, industry advisors, researchers and community organisations.

The Guidelines will shortly be available on the Department of Environment and Climate Change website at www.environment.nsw.gov.au. For further information contact Mitch Tulau from the NSW Department of Environment and Climate Change on (02) 6561 4978 or Mitch.Tulau@environment.nsw.gov.au.

Tulau, M.J. (2007). Acid Sulfate Soils Remediation Guidelines for Coastal Floodplains in New South Wales. Department of Environment and Climate Change. ISBN 978 1 7412 493 1 DECC 2007/321.

Restoring Watercourses, Wetlands & Coastal Lakes on the NSW North Coast

An alliance of North Coast Councils has secured $1.9 million to tackle floodplain issues across a large region of the NSW north coast. This multifaceted project will deliver significant works, primarily in acid sulfate soil areas, resulting in effective and lasting responses. The six participating councils are the Tweed Shire, Richmond River, Clarence Valley, Port Macquarie Hastings, Kempsey and Greater Taree, all members of the NRCMA Floodplain Network. This network enables members to take a collaborative approach to floodplain management and share information and develop resources and tools.

Aerial view of the Clarence Valley floodplain

Over the next three years, serious floodplain issues such as 'blackwater' events, acid sulfate soils, stormwater pollution, nutrient run-off, aquatic weeds, barriers to fish passage, wetland deterioration, vegetation management and erosion will be addressed.

The North Coast Councils will undertake on-ground works including the installation of weirs, winches and tidal gates, establishment of native vegetation on floodplain watercourses, and restoration of wetlands. Community engagement will take place through educational field days and newsletter publications. A key component will be the involvement of landholders in all stages of project planning and management, including the establishment of Drain Management Plans and the modification and active management of flood control structures.

By working in partnership with local landholders, more natural drainage will be reinstated in degraded wetlands to improve water quality, reduce acid discharge, reinstate habitat for wildlife and waterbirds and improve passage for fish and other aquatic fauna. These outcomes will contribute to improving the health of the North Coast floodplains, benefiting the environment, agriculture, tourism, local fisheries and coastal communities.

This project has been made possible with the financial support of the NSW Environmental Trust's Urban Sustainability Program which provides major grants for projects that will resolve environmental issues and will deliver sustainable environmental, social and economic outcomes.

For further information contact Project Manager Fiona McPherson, Clarence Valley Council on (02) 6641 7350.

Managing wet pasture systems

There is growing landholder interest in the management of wet pasture systems on the north coast of NSW (and elsewhere). The environmental benefits of retaining or re-establishing wet pasture systems are many, for example: reducing the exposure of potential acid sulfate soil; minimising acid discharge into waterways and black water formation; and improving waterbird and fish habitat. However, information on how to sustainably manage these systems and what the production benefits for landholders are, have until now, been largely non-existent.

Hence, NSW Department of Primary Industries established the Floodplain Grazing Project with funding assistance from the Northern Rivers Catchment Management Authority through the National Landcare Program. Its aim was to raise grazier's awareness & knowledge of best management practices for the use of wet pasture systems to remediate acid sulfate soils.

The project collected data on the feed quality of 12 common coastal wetland species. In conjunction with the NSW DPI Wet Pastures project, the Floodplain Grazing Project has shown landholders that certain types of wet pasture systems can be highly valuable for livestock production if managed correctly. For example, pastures based on water couch (*Paspalum distichum*) can yield as much as kikuyu over summer, while having similar or better quality.

To help landholders better understand and manage their wet pasture systems, the project produced the following information sheets: "Establishing a Wet Pasture System"; "Black Water"; "Water Couch"; Water Couch Growth and Productivity"; and "Feed Quality of Coastal Wet Pastures". A case study booklet called "Grazing the Coastal Floodplain: Stories of Sustainable Practice" highlighted the many ways that landholders are already successfully managing their floodplain country. These are (or very soon will be) available on the NSW DPI web site and/or from departmental offices. Information sheets on common wet pasture species were also produced in conjunction with the Paddock Plants project.

Field days were run on the north coast in autumn 2008 to let land managers know about project's results. The extent of interest in wet pasture systems and acid sulfate soils were revealed by the large number of landholders, council officers and other community members who attended the days.

Carol Rose (NSW DPI) collecting quality samples in a Macleay Valley wetland

Landholder's discussing wetland management at a Clarence Valley field day

For more information contact Harry Rose (NSW DPI) harry.rose@dpi.nsw.gov.au or Chrisy Clay (NSW DPI) christina.clay@dpi.nsw.gov.au

Acid Sulfate Soil Assessments in Port Stephens

The Anna Bay catchment is a 450 hectare coastal back-swamp on the Tomaree Peninsula of Port Stephens, NSW. Since initial drainage works over 100 years ago to improve agricultural land, the drainage network has been considerably extended and discharges into the Port Stephens-Great Lakes Marine Park. In recent years there has been increasing recognition of the potential for negative impacts due to exposure of the underlying acid sulfate soils in the catchment. Greater movement of acidic groundwater has resulted in fish kills, poor water quality affecting oyster cultivation, an acidification event, reduced stock production and a deterioration in downstream environmental values.

NSW DPI has recently completed the first phase of an ASS assessment and remediation project for the Anna Bay catchment in Port Stephens. The project was funded by the Hunter-Central Rivers CMA to determine the extent of ASS in the catchment and implement remediation options to improve the water quality being discharged into the Marine Park's Sanctuary Zone.

Main drain stained orange with iron floc

Detailed on-ground assessments in the current study confirmed previous studies that showed ASS occurs at shallow depths in the catchment and in some areas less than 1 m below the surface. Soil and drain and ground water testing also confirmed ASS oxidation has occurred and continues to do so due to groundwater draw-down during drier periods. Water sample testing showed water quality in the drainage system rarely met the criteria set by the ANZECC water quality guidelines for the protection of aquatic ecosystems.

The assessments identified two high-risk 'hot-spot' ASS areas within the catchment. These areas have shallow sulfidic material combined with the poorest water quality, extremely high levels of iron and aluminium and low pH values. After extensive consultation with local landholders, ASS experts and state and local government, remediation actions are currently underway to reduce oxidation and eventual acid discharge. These actions include:

- Strategic application of lime for all past and future soil disturbance;
- Raising the height of several side drainage pipes to reduce intersection of the sulphate layer and groundwater drainage;
- Installation of a low set weir to reduce over-drainage at a key hotspot, while widening the drain at that point to ensure drainage capacity is not reduced;
- Install additional floodgate cells at the existing structure to enhance drainage capacity of the overall system, while modifying one floodgate to enable controlled tidal exchange.

Mono-sulfidic black ooze on the surface of one 'hot-spot' area

For further information contact Adrianne Burke, NSW Department of Primary Industries on 02 4916 3846 or adrianne.burke@dpi.nsw.gov.au.

ASS Investigations in Lower Hunter Estuary Wetlands

A project on the NSW Lower North Coast, entitled 'Acid Sulfate Soils Priority Investigations in the Lower Hunter River Estuary', has recently been completed by NSW Department of Primary Industries. The project was funded by the Australian Government's Coastal Catchments Initiative.

Soil Chemist Roy Lawrie collecting a soil core at Tomago Wetlands

Soil coring, profile description, laboratory analysis, and tests for soil hydraulic conductivity (K_{sat}) and electrical conductivity (EC) were carried out to assess acid sulfate soils (ASS) distribution and severity in the Lower Hunter wetlands. In addition, elevation information (LiDAR) was used to update the Acid Sulfate Soil Risk Maps for the study area.

Study areas included Kooragang and Shortland Wetlands (which are both listed as Ramsar Wetlands of International Importance), as well as nearby Tomago Wetland, Hexham Swamp and Fullerton Cove. Analyses of soils have revealed that ASS occur in all five of the sites, at differing degrees of severity. Waterlogging of soils has reduced the amount of stored acid in the profile at many sites.

Fullerton Cove and Tomago Wetland are considered the highest priority sites for ASS management of the five wetland sites tested, because there is more actual acid stored in the soil profile.

At both sites opening the floodgates is recommended to reintroduce tidal water into the drains to neutralise and dilute acid before it reaches the estuary. This recommendation builds on an existing project that is proposing to open one of Tomago Wetland's floodgates.

At Hexham Swamp and Shortland Wetlands high risk areas are concentrated near low lying areas near Ironbark and Fishery Creeks. The study's recommendations support an existing proposal to open Ironbark Creek floodgates to restore tidal flushing into these creeks and manage acid leachate.

Kooragang Wetland (Ash Island) is considered a medium ASS risk site. Areas to the north of the wetland have high stored acidity within the soil profile, while permanently inundated ponds in the south are actively accumulating sulfides on the soil surface. Maintaining or enhancing the natural water management regime (tidal influence without artificial drains) is a priority at this site.

Iron floc in Fishery Creek at Hexham Swamp

NSW DPI is looking to work with landholders and land managers to implement recommended ASS management options in the future.

For further information contact Jenny Fredrickson, NSW Department of Primary Industries on (02) 4916 3834 or jenny.fredrickson@dpi.nsw.gov.au.

Acid Sulfate Soils: Identification, Assessment & Management Short Course

Southern Cross GeoScience is running a short course on the 11th, 12th & 13th November 2008 at Lismore. The course is designed to equip professional officers charged with the management of acid sulfate soils with the knowledge and skills to develop and administer an acid sulfate soil plan of management in accordance with NSW legislative requirements. The course consists of lectures, practical exercises and field excursions.

Day 1 is an introduction to acid sulfate soils and covers: the definitions, distribution and importance of acid sulfate soils; an introduction to relevant NSW legislation and guidelines; desktop and field test assessment of acid sulfate soils; and a field trip to local acid sulfate soil sites, involving field sampling and testing.

Day 2 covers the assessment and management of acid sulfate soils, including: laboratory analysis of acid sulfate soils; understanding and interpreting field and laboratory results; and mitigation and management strategies.

Day 3 involves developing an acid sulfate soil management plan. It covers elements of an acid sulfate soil management plan in NSW and the development of a comprehensive acid sulfate soil management plan using a case study.

The course will be lead by Professor Leigh Sullivan, Scott Henderson and Crystal Maher. The cost is AU$1500.00 (plus GST), which includes tuition, course notes, field excursions, refreshments and lunches.

For more information email the Centre for Acid Sulfate Soil Research at cassr@scu.edu.au

Draft Strategy for Coastal Acid Sulfate Soils in Victoria

A draft Strategy for Coastal Acid Sulfate Soils in Victoria has been launched (11 June 2008), for a period of 8 weeks for public comment. The Strategy sets an objective, decision making principles and actions for CASS in Victoria. Ministers' for Environment and Climate Change, Water, Planning, and Agriculture have agreed on their respective roles and responsibilities.

The first principle in the draft Strategy is to avoid disturbing CASS. A risk management approach is proposed in order that decisions are made having regard to known risks, to ensure the consequences of activities in CASS areas are nullified or reduced, through implementation of best practice assessment and management techniques.

The Strategy can be viewed at http://www.dse.vic.gov.au/DSE/nrencm.nsf/LinkView/8731022F1213F1FACA2572D000063C53DF4F1A9C76516D364A2567CA008177DF

Tidal inundation remediates acid sulfate soils at East Trinity Inlet, Cairns

The severe acid sulfate soils at East Trinity Inlet appear to have undergone a remarkable transformation due to the introduction of regular tidal inundation. The success of the remediation program so far is attracting national and international attention. In a project funded by CRC CARE, Southern Cross University (SCU) and Qld DNRW, teams from SCU and DNRW have been investigating the effects of tidal inundation on water quality and soil geochemistry. Initial findings are very encouraging.

A study of water quality trends over the last 5 years provides strong evidence that regular tidal inundation has dramatically improved surface water quality. "There were significant increases in the pH of tidal creeks after introduction of regular tidal inundation", said Dr Scott Johnston, a research associate from Southern Cross University. "There was also much less acidity being exported per given amount of antecedent rainfall. This demonstrates there has been a fundamental shift in the acid export dynamics at the site and water quality has improved tremendously as a result."

Tidal waters flowing through open floodgates at East Trinity

Another study examined some severely acidified soils before and after ~5 years of regular tidal inundation. Soil pH increased by 2–3 units in former sulfuric horizons and titratable actual acidity (TAA) decreased by about 40–50 mol H^+ per tonne. There was also considerable reformation of pyrite within the former sulfuric horizons after tidal inundation.

"These decreases in soil acidity and the accumulation of pyrite have effectively turned sulfuric horizons into sulfidic horizons" said Dr Johnston. "Evidence to date suggests that the decreases in soil acidity are due to a combination of marine alkalinity inputs and internally generated alkalinity due to reduction of both iron and sulfate. Tidal inundation is harnessing natural soil bacteria to consume acidity – essentially the same processes that created the pyrite in the first place".

Sulfide-rich surface sediments at East Trinity reformed as a result of regular tidal inundation

The results so far clearly demonstrate that re-establishing marine tidal inundation has considerable potential as a landscape-scale strategy for ameliorating severe acid sulfate soils in coastal landscapes. However, further assessments are required to better understand key geochemical processes and the stability of the remediation.

For further information contact the project leader, Professor Richard Bush at richard.bush@scu.edu.au.

Community ASS workshop

WA's Department of Environment and Conservation (DEC) has taken its acid sulfate soils (ASS) community workshop to the road. Targeted at community landcare groups, local and state government agencies and industry representatives, the workshop is run on a regular basis as part of DEC's community education programme on ASS.

The most recent workshop was held in Mandurah, which is, like many coastal regions of Western Australia, a high risk ASS area facing potential environmental damage if urban development on affected sites is not managed properly.

DEC's acid sulfate soils section manager Stephen Wong said exposure of poorly managed ASS in the Peel region following urban and canal developments and maintenance dredging operations had caused considerable harm to the receiving environment.

"These activities have caused sulfidic soils to oxidise and produce acidic conditions in the soils and groundwater," Mr Wong said. "Historically dredge spoil deposits were dumped on land around the Peel Estuary and islands created within the estuary. The extent to which this material is acidifying is largely unknown and in the meantime, this activity is likely to increase with urban development pressures in the region."

A study conducted by the Centre for Coastal Management in 2006 found significant monosulfidic black ooze formation in South Yunderup channel and that the environmental consequences of continual dredging had not been fully characterised or quantified.

"Community workshops are one way to promote awareness of inappropriate ASS disturbance and effective ways of managing urban development in affected areas," Mr Wong said. "We want people to be able to recognise the symptoms of acid sulfate soils because they are becoming a major environmental issue in areas of coastal and inland Western Australia. If disturbance of acid sulfate soils cannot be avoided, affected areas must be managed correctly to prevent these serious environmental problems."

The workshop included a field trip in the South Yunderup area where participants could see the damage caused by badly managed development on acid sulfate soils.

Workshop participants head out to a former dredge spoil disposal site adjacent to the Murray River. Here, water is highly acidic (pH<3) and loaded with soluble metals and other contaminants.

DEC's next workshop is a technical one aimed at environmental consultants and associated professionals. The intensive two day program is packed with the latest ASS related information and has keynote speakers from Australia wide.

ASS Awareness Online

Western Australians can now access new information on ASS via the Department of Environment and Conservation's website.

A series of factsheets on ASS can be viewed by visiting http://www.dec.wa.gov.au/ass

The four factsheets aim to make information on ASS available to the public in an easy to read, non technical format. Titles include --

- What are acid sulfate soils?
- Recognising disturbed acid sulfate soils
- Acid sulfate soil risk maps
- Managing urban development in acid sulfate soil areas

Fact sheets, banners and bumper stickers form part of a multi-pronged ASS awareness campaign

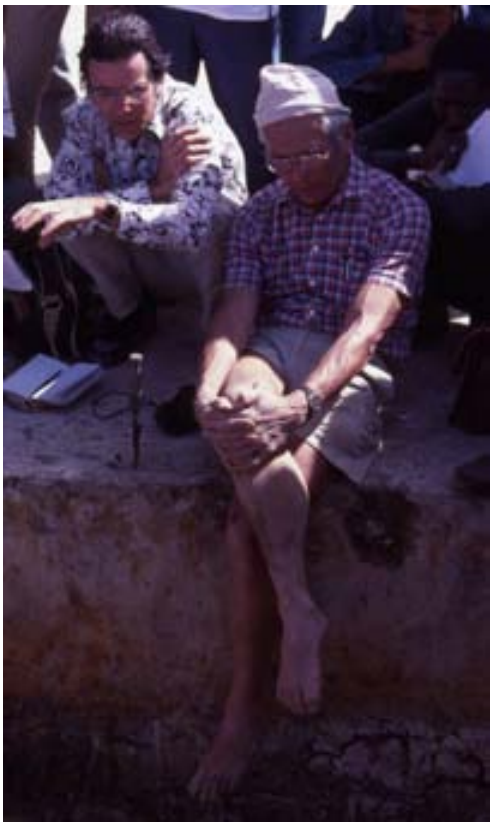
Leen Pons, Father of the International Acid Sulfate Soils Symposia/Conferences

By Del Fanning, DelvinDel@aol.com

Leendert Japhet Pons, Emeritus Professor at Wageningen University in the Netherlands, died from cancer on June 16, 2008 at age 87. Those who knew Leen by way of the international acid sulfate soil symposia/conferences have many pleasant memories of him. Leen had a strong hand in organizing the symposia in the Netherlands, Thailand, Malaysia, West Africa and Vietnam from 1972 to 1992. He was a special guest of the 5th international conference in Tweed Heads in 2002. He will be missed at the 6th conference in Guangzhou this year.

Leen may truly be called the "Father of the International Acid Sulfate Soil Symposia/ Conferences". The term acid sulfate soils came into use, presumably through his guiding influence, at the time of the first symposium in Wageningen in 1972. Previously, such soils were commonly called "cat clay soils", or *Kette Klei* in Dutch. Leen is especially known for concepts of the physical ripening of soft sediments/soils. The *n*-value, which was incorporated into *Soil Taxonomy* (Soil Survey Staff, 2006 and earlier versions), is used to evaluate various stages of the ripening of soil materials that constitute acid sulfate soils, especially in coastal areas.

Leen (above) doing the squeeze test to show how half-ripe and softer soil materials would squeeze out between ones fingers



Leen (right) and former student Robert Brinkman discussing acid sulfate soils in Guiné Bissau in 1986

Leen contributed to the training of many students and colleagues who themselves have made many contributions to knowledge about and to improved management of acid sulfate in many places around the world.

Leen was author and/or co-author of many papers dealing with various aspects of acid sulfate soils. Tini van Mensvoort from Wageningen, who was a leader of the soil survey of Vietnam in the 1980's, points out that Leen was very influential in that work, which left Vietnam with a solid cadre of scientists knowledgeable about acid sulfate soils who continue to conduct research and contribute to the wise management of acid sulfate soils.

I am sure that everyone who knew, or now feel they know, Leen and his many contributions to acid sulfate soil science wish to express their grief and sympathies to his wife Nadia and all members of the Pons family.

This is only an extract from the tribute that was written by Del Fanning. If you would a full copy of the tribute, please contact the Information Officer on (02) 6562 6244 or harry.rose@dpi.nsw.gov.au

Acid sulfate soils reduce estuarine productivity

Dove, M.C. and Sammut, J. (2007) Impacts of estuarine acidification on survival and growth of Sydney rock oysters *Saccostrea glomerata* (Gould, 1850). Journal of Shellfish Research, 26:519-527.

Sydney rock oysters are farmed in estuaries, primarily in NSW and southern Qld. It is an important commercial species, generating around $27 million USD per year in NSW alone. Over the last 30 years, production has dramatically declined. In part, this is due to disease outbreaks, competition from Pacific oysters and declining water quality. However, episodic acidification of estuarine waters from acid sulfate soils has also been implicated.

Laboratory experiments (see ASSAY No 44 p10) have shown that the feeding rate of Sydney rock oysters is reduced when exposed to acidified water. If aluminium or acid sulfate soil by-products are present in the water, changes to soft tissues quickly occur.

This paper discusses the effects of water acidification on the survival and growth of Sydney rock oysters under actual estuarine conditions on the Manning River, NSW, Australia. Water quality and oyster survival and growth were measured for seven months at seven sites in this estuary.

Sites located close to acid sulfate soil outflows had low pH values (< 4.5), reduced salinities and high levels of iron and aluminium in the water. These sites had significantly higher oyster mortality compared to sites that were not acidified. Small oyster mortality was significantly higher than large oyster mortality during the experiment. Also, small and large oysters at sites that were acidified had significantly reduced growth compared to the oysters at sites which were not acidified.

ASS-affected water moving over oyster leases at the mouth of Cattai Creek, Manning River

For a copy of the above paper, contact the Information Officer on (02) 6562 6244 or harry.rose@dpi.nsw.gov.au

Acid sulfate soils and oil production in Nigeria

Ohimain, E. (2006) Indicators of wetland acidification and their relevance to impact assessment. CBBIA Small Grants final report (2004SGP04). Int. Assoc. for Impact Assessment, Fargo, USA.

Oil exploration is the major economic activity in the Niger Delta, accounting for nearly 90% of Nigeria's earnings. In 1997 there were 159 oil fields, increasing to 481 by 2002, and the number of producing companies is increasing annually. The entire delta is a wetland of over 76,000 km^2, with mangroves (potential acid sulphate soils) occupying about 10,000 km^2, mostly along the Atlantic coastline. This represents about 20% of the total known area of acid sulfate soils in Africa.

Vegetation damage caused by acidification from a recently dredged canal.

Oil exploration and production have the potential to cause acidification across large areas. For instance, a major oil producing company whose operations cover 31,000 km^2, has been reported to have cut 90.5 km^2 of seismic lines through wetlands, of which 57 km^2 were through mangroves.

Canalization is also extensive in the delta, especially in the mangrove zone. Between 1980 and 1988 government agencies have dredged 100km of wetland canals in the Rivers State, while a major oil producing company has dredged 71 km^2 of mangrove canals in the last 50 years. On average, several kilometres of spoil banks are produced annually.

Most oil-well canals are large (e.g. 25-30m wide and to 3.5m deep); creating large amounts of spoil. For example, a major oil producing company in the delta generated approximately 20 million cubic metres of dredged materials between 1990 and 1996. The amount of dredged material has increased considerably over time due to: the nearly 50 years of oil operations; expanding exploration; and high sedimentation rates, which often necessitate frequent maintenance dredging.

Impact assessment studies appear not to have adequately addressed biodiversity issues relating to coastal developments in wetland areas, particularly for sensitive ecosystems like mangroves. Acidification, causing biodiversity loss and general habitat damage, often accompanies these developments

Abandoned spoil undergoing acidification

It has been reported that the reduction in fisheries in the delta coincided with the advent of oil exploration. Although other factors (e.g. population increases, over-harvesting and dam construction) were probably involved in the decline, habitat degradation caused by dredging and subsequent acidification may have also contributed substantially.

For a copy of the above report, contact the Information Officer on (02) 6562 6244 or harry.rose@dpi.nsw.gov.au

Acid sulfate soils cause extensive metal pollution of estuarine sediments

Nordmyr, L., Åström, M. and Peltola, P (2008). Metal pollution of estuarine sediments caused by leaching of acid sulphate soils. Estuarine Coastal and Shelf Science, 76:141-152.

As in many parts of the world, the coastal plains of Finland are underlain by waterlogged sulphidic sediments. Over the last century, the plains have been developed for agriculture by burning the peat cover and installing deep drains. This has exposed the sulfidic layers, resulting in actual acid sulfate soils that cover between 43,000 – 130, 000 hectares.

The extent of the metal discharge into the environment from these soils is greater than that from the entire Finnish industry. Consequently, frequent fish kills now occur in the coastal streams and estuaries.

The outlet of the Vörå River, draining acid sufate soils.

However, little is known of the fate of these metals as they enter the estuaries. This paper discusses the changes in metal distribution in estuarine sediments extending from the mouth of the Vörå River. The Vörå River is one of the most severely acid sulfate soil affected rivers in Finland, with pH readings that are occasionally as low as 4.

Even at 4km from the river mouth, metals known to be extensively leached by acid sulphate soils (Cd, Co, Mn, Ni and Zn) where found at 5 – 100 times that of background levels. By contrast, metals that aren't mobilised by acid sulphate soils were not found at elevated levels in the sediments.

The authors suggest that acid sulphate soils may have significant effects on trace-metal levels for the entire Baltic Sea and that similar extensive metal contamination of biologically sensitive estuaries are likely to occur elsewhere in the world where acid sulphate soils are common

For a copy of the above paper, contact the Information Officer on (02) 6562 6244 or harry.rose@dpi.nsw.gov.au

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ACID SULFATE SOILS